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TITLE INDUSTRIAL APPLICATIONS OF HOT DRY ROCK GEOTHERMAL ENERGY

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INDUSTRIAL APPLICATIONS OF HOT DRY ROCK GEOTHERMAL ENERGY

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Abstract- Geothermal resources in the form of naturally occurring hot water or steam have been utilized for many years. While these hydrothermal resources are found in many places, the general case is that the rock at depth is hot, but does not contain significant amounts of mobile fluid. An extremely large amount of geothermal energy is found around the world in this hot dry rock (HDR).

Technology has been under development for more than twenty years at the Los Alamos National Laboratory in the United States and elsewhere to develop the technology to extract the geothermal energy from HDR in a form useful for electricity generation, space heating, or industrial processing. HDR technology is especially attractive for industrial applications because of the ubiquitous distribution of the HDR resource and the unique aspects of the process developed to recover it.

In the HDR process, as developed at Los Alamos, water is pumped down a well under high pressure to open up natural joints in hot rock and create an artificial geothermal reservoir. Energy is extracted by circulating water through the reservoir. Pressurized hot water is returned to the surface through the production well, and its thermal energy is extracted for practical use. The same water is then recirculated through the system to mine more geothermal heat. Construction of a pilot HDR facility at Fenton Hill NM, USA, has recently been completed by the Los Alamos National Laboratory. It consists of a large underground reservoir, a surface plant, and the connecting wellbores.

This paper describes HDR technology and the current status of the development program. Novel industrial applications of geothermal energy based on the unique characteristics of the HDR energy extraction process are discussed.

INTRODUCTION

All commercial geothermal energy plants operating today involve the extraction of heat from naturally occurring hot water or steam sources. While these hydrothermal resources occur at scattered locations on all continents, they represent only a small fraction of the geothermal energy that exists at accessible depths within the earth. By far the largest amount of geothermal energy is found in the form of hot dry rock (HDR), which is found almost everywhere at depth.

For more than twenty years, the United States Department of Energy and its predecessor agencies, working through the Los Alamos National Laboratory, have been developing the technology to gain access to and mine the thermal energy in HDR. This paper describes the HDR technology developed at Los Alamos, compares the process used to extract HDR energy with that employed for conventional hydrothermal resources, and suggests potential industrial uses for HDR.

THE HDR HEAT MINING CONCEPT

A concept for mining the heat within the earth was patented by researchers at Los Alamos in 1974 (Potter et al). It describes a system similar to that illustrated in Figure 1.

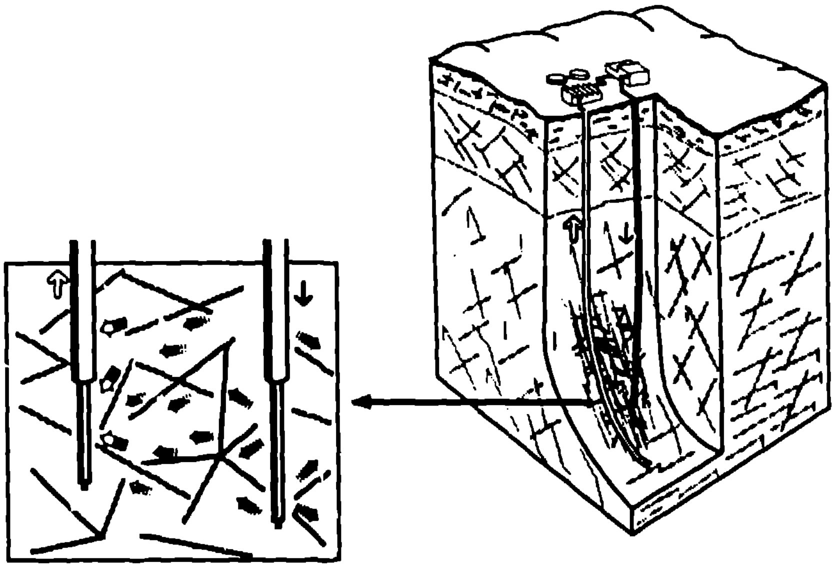

Figure 1. An HDR heat mine. The inset shows typical fluid flow paths through the hot rock reservoir.

To construct such an HDR system, a well is drilled to deep enough to reach usefully hot rock. An artificial reservoir consisting of a relatively small amount of water dispersed in a large volume of rock is then created in the hot rock by hydraulic fracturing which uses water under high pressure to open up natural joints in the rock. A second well is subsequently drilled to penetrate the reservoir at some distance from the first.

In operation, water is pumped down one well, across the reservoir under pressure, and back to the surface through the second well. As it traverses the reservoir, it picks up thermal energy from the hot rock. At the surface, this energy is extracted and applied for useful purposes. The cooled water is then recirculated through the system to mine more heat.

When run in a closed-loop mode as described above, an HDR facility has minimal effects on the environment. Only heat is released to the atmosphere as a result of normal operations and there is no effect on surface or ground waters. Unlike a coal-fired power plant, HDR energy is stored underground so the surface facility need occupy only a small amount of space. Finally, no long term residues accumulate to present eventual disposal problems.

The rate at which the temperature of rock increases with depth, the geothermal gradient, is the primary factor in determining the quality of HDR resources. High geothermal gradients usually occur in regions of active volcanism or mountain growth. Figure 2 shows a geothermal gradient map of the United States.

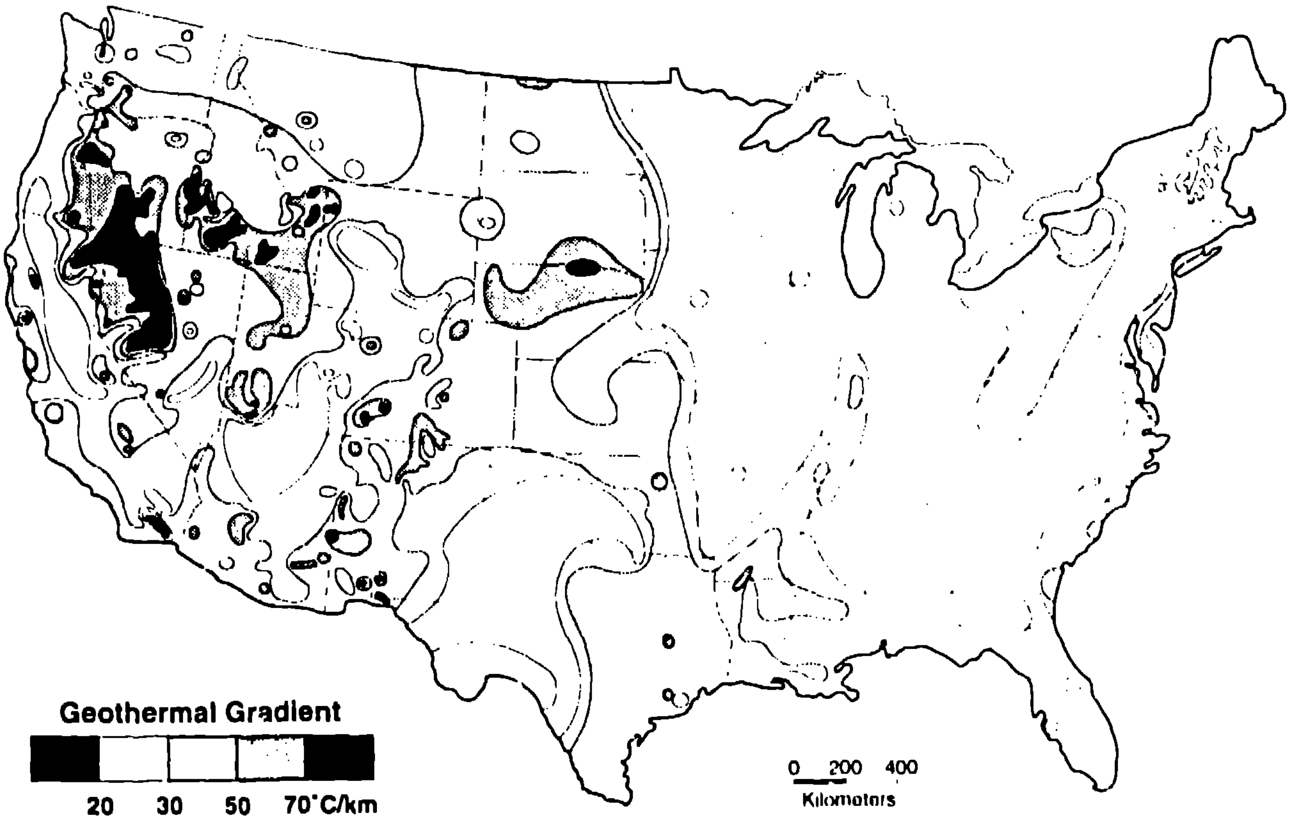

Figure 2. A geothermal gradient map of the United States. High grade HDR resources are found in the western part of the country.

It is clear that HDR is found closest to the surface, and thus is most accessible, in the western part of the country. Japan, like the western US, has an abundance of high grade HDR resources while in northern and western Europe HDR is generally found at somewhat greater depths.

Economic Studies have indicated that industrial heat could be produced from HDR for about $2US to $20US per million kilojoules, depending upon the quality of the resource, and that electricity could be generated from high grade resources for $0.05-0.07US per kilowatt hour (Tester and Herzog 1990). These studies assume that drilling technology currently available and optimized reservoir creation techniques would be used to construct the HDR system. On the basis of the above figures, practical applications of HDR at some locations may already be within reach on an economic basis. As the technology matures, and new ideas which have been conceived but not tested are brought to fruitic , HDR is expected to become a viable resource for a greater variety of industrial and commercial processes over an ever-widening geographical area.

HDR TECHNOLOGY DEVELOPMENT AT LOS ALAMOS

Construction of a small HDR heat mine was begun in 1974 at Fenton Hill about 60 kilometers west of Los Alamos in the mountains of northern New Mexico. The geothermal gradient at this location is about 65°C/km which is moderately high but not outstanding. Between the years of 1978-1980, this small heat mine was operated intermittently for a total running time of more than a year (Dash et al 1981). About 5-6 l/s of water was produced at temperatures in the range of 135-140°C. This experiment demonstrated that it is possible to mine the heat within the earth using the technology described above.

Between 1980 and 1986, a larger, deeper, and hotter heat mine was developed at Fenton Hill. A short flow test of this system was conducted in 1986.(Dash 1989). During this 30-day test, production reached more than 12 l/s of water at a temperature of nearly 200°C. By the end of the test, about 74% of the injected water was being returned to the surface. Seismic analyses of microearthquakes which occurred during the test indicated that, at the high injection pressure being employed (31 MPa), much of the water was being consumed in expanding the volume of the reservoir.

The 30-day test was run with an improvised surface facility and rented equipment. On the basis of the encouraging test results, the underground portion of the system was improved to make it more durable (Dreesen et al 1989) and a permanent surface plant was constructed (Ponden 1991). At the same time, static reservoir pressurization tests were carried out to gain a better understanding of water consumption in HDR systems. They indicated that, when the pressure on the system was kept below the level that would cause reservoir growth, water consumption declined with time to an extremely low level (Brown 1991).

In the spring of 1992, a long-term flow test (LTFT) of the larger Fenton Hill reservoir was begun. This test is being conducted with an injection pressure of 27 MPa, just below the level which would cause reservoir expansion as indicated by microearthquake events. In addition, a substantial backpressure is being applied to the production wellbore since studies have indicated that this aids in opening the joints near the reservoir outlet.(Robinson and Brown 1990).

As of late June 1992, the test has been underway on a continuous basis for nearly three months with the exception of a few short interruptions due to electrical outages affecting the surface plant. Important operating parameters as of June 25 are summarized in Table 1.

Table 1

HDR System Operating Parameter as of June 25, 1992			
Injection		**Production**	
Pressure	27.2 MPa	Pressure	9.7 MPa
Flow Rate	7.09 l/s	Flow Rate	6.08 l/s
Temperature	20 °C	Temperature	185 °C
Net water consumption (24 hour average) 10.1%			

The test results to date have been extremely encouraging. The system has run so reliably as to be practically routine, providing solid evidence that HDR plants can be adapted to the relatively straightforward conditions required for commercial operations. It is difficult to quantify net energy production without resorting to a number of assumptions because only thermal energy is being produced while both diesel and electric power are used to run the plant. It seems clear, however, that the system is a net power producer since the calculated pumping power is only about 3% of the thermal power generated. On a cost basis, for each kilowatt of thermal energy produced, about $0.003US is being spent for diesel fuel and electricity to run the system.

The LTFT will be continued at least through September, 1991. If adequate funding is received the test will be operated for a year or more and a variety of methods for optimizing the operation of the system will be investigated.

HDR WORK IN OTHER COUNTRIES

In addition to the United States, a number of other nations are investigating HDR technology (Duchane 1990). Large HDR research and development efforts have been underway in Great Britain and Japan for a number of years. The European Community (CEC) is also sponsoring the development of HDR in relatively low gradient resource areas in conjunction with organizations in France, Germany, and recently, Great Britain. The Russians have had a longstanding interest in HDR and began experimental work near Tirniaus in the Caucuses Mountains of southern Russia in 1989. Sweden and Switzerland have also carried out more limited work on HDR.

THE HDR PROCESS COMPARED TO HYDROTHERMAL TECHNOLOGY

HDR and hydrothermal resources are fundamentally similar in that they both rely on the heat of the interior of the earth as the ultimate energy source. There are some important differences between the energy extraction techniques, however, which have important implications for industrial applications. Hydrothermal energy production systems utilize naturally occurring hot fluids which are drawn from a more-or-less open network of natural fractures. In contrast, an HDR heat mine is essentially a closed system with fluid supplied from an external source and continually recirculated through an essentially closed system. While hydrothermal reservoirs are a product of nature, HDR reservoirs are man-made.

Because of the above facts, it should be possible to locate HDR facilities at a much wider variety of sites, design HDR reservoirs with greater flexibility, construct HDR systems on a more fully-engineered basis, and operate HDR plants within tighter control limits than is possible for hydrothermal installations. Indeed, HDR technology changes geothermal energy in general from a resource which is geographically and technically limited to one which has truly global potential and much more versatile application possibilities. While HDR can be applied to the same industrial uses as hydrothermal energy, its development opens up a number of additional potential industrial applications. Two of these are addressed in this paper.

POTENTIAL INDUSTRIAL APPLICATIONS OF HDR GEOTHERMAL ENERGY

Perhaps the most important unique characteristic of HDR systems from an industrial applications standpoint lies in the fact that water is supplied to extract the thermal energy. When operated solely as an energy producer, the water is continually recycled for conservation purposes but it is possible, of course, to operate the system in a single pass mode or with only partial recycling. With this in mind, one obvious industrial application involves the purification of seawater, certain industrial wastewaters, or treated domestic sewage by circulation through an HDR reservoir.

Figure 3 is a diagram of how such a system might work. The water to be treated is used to feed the system. It is sterilized and organic contaminants are destroyed when it is heated under very high pressure in the reservoir. At the surface, it can be be flashed to steam to both generate electricity and complete the purification process. In this plan, an HDR facility could serve the joint purposes of water purification and energy production If the supply of feedwater were limited, a portion of the produced fluid could be recirculated in order to maintain a steady level of energy production while the balance of the purified water could be applied for beneficial uses such as agriculture or domestic consumption.

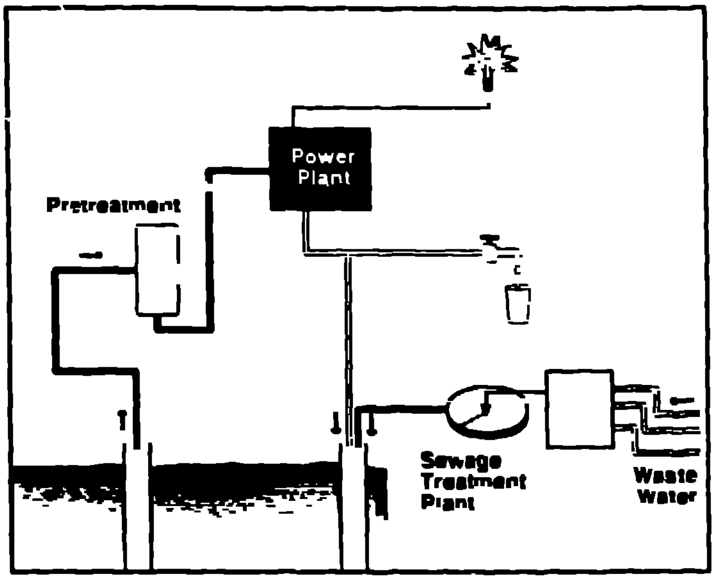

Figure 3 An HDR plant designed for both water purification and electricity production Part of the pure water produced may be recycled if necessary to keep the energy production rate constant

Since an HDR reservoir is essentially a closed system, it might also be possible to utilize an HDR system as a high temperature/high pressure chemical reactor. Certain chemical products (large chain ring compounds, for example) can be produced most efficiently by reactions in extremely dilute solutions. This is often not practical for reactions that occur at elevated temperatures and/or pressures because of the problems of containing an extremely large volume of fluid while heating and pressurizing it An HDR reservoir provides an ideal reactor for such applications which can be designed to be inherently safe if environmental factors are taken fully into account

Of course, environmental considerations must play an critical role in any industrial applications of HDR Water purification processes must be limited to those where there can be no danger of the production or build-up of toxic substances There are a wide variety of so-called gray water sources where this is not likely to be a problem Obviously, for the use of an HDR reservoir as a chemical reactor, the circulating fluid solvent as well as all dissolved species must be environmentally harmless Potential solvents which might well meet such criteria include water, liquid carbon dioxide and ammonia Reactants encompass a wide range of compounds which present no environmental threat when present in relatively small quantities in dilute solution

At present, the primary goal of HDR research and development is to prove that energy can be delivered to the surface from an HDR reservoir on a reliable basis over an extended time period The generation of electricity at competitive costs is foremost in the mind of those interested in the application of HDR technology As this goal is achieved and the development of HDR reservoirs becomes more routine, other industrial uses such as those described above will undoubtedly be developed.

SUMMARY

HDR geothermal energy is much more abundant and widespread than conventional hydrothermal energy resources. For over twenty years, work has been underway at Los Alamos National Laboratory in the United States as well as in many other parts of the world to develop the technology to mine the thermal energy from HDR. A long-term test to demonstrate that HDR heat mines can deliver energy reliably and on a sustained basis is currently underway at Fenton Hill, NM.

HDR heat mines can be used to supply energy for the same types of industrial applications as hydrothermal resources, but additional uses can also be developed due to the unique nature of the HDR process. Water purification and novel chemical syntheses are but two of the potential industrial applications for which HDR may be applied. The initial application of HDR technology will most likely involve the generation of electric power, but as HDR technology becomes more established, numerous industrial use will be found for this ubiquitous energy source. Water purification and specialized chemical syntheses in HDR systems are but two promising industrial applications.

REFERENCES

Brown, D. W., 1991. Recent Progress in HDR Reservoir Engineering, Proceedings of U. S. Department of Energy Geothermal Program Review IX, pp 153-157.

Dash, Z. V., ed., 1989. ICFT: An Initial Closed-Loop Flow Test of the Fenton Hill Phase II HDR Reservoir, Los Alamos National Laboratory Report, LA-11498-HDR.

Dash, Z. V., H. D. Murphy, and G. M. Cremer, eds., 1981. Hot Dry Rock Geothermal Reservoir Testing: 1978-1980, Los Alamos National Laboratory Report, LA-9080-SR.

Dreesen, D. S., G. G. Cocks, R. W. Nicholson, and J. C. Thomson, 1989. Repair, Sidetrack, Drilling, and Completion of EE-2A for Phase II Reservoir Production Service, Los Alamos National Laboratory Report, LA-11647-MS.

Duchane, D. V., 1991, International Programs in Hot Dry Rock Technology Development, Geothermal Resources Council Bulletin, 20, 5, May, pp 135-142.

Ponden, R. F., 1991. The Design and Construction of a Hot Dry Rock Pilot Plant, Proceedings of U. S. Department of Energy Geothermal Program Review IX, pp 1149-151.

Potter, R. M., E. S. Robinson, and M. C. Smith, 1974. Method of Extracting Heat From Geothermal Reservoirs, U. S. Patent 3,786,858.

Robinson, B. A. and D. W. Brown, 1990. Modeling the Hydraulic Characteristics of the Fenton Hill, New Mexico Hot Dry Rock Reservoir, Geothermal Resources Council Transactions, 14, II, August, pp 1333-1337

Tester, J. W. and H. J. Herzog, 1990. Economic Predictions for Heat Mining: A Review and Analysis of Hot Dry Rock (HDR) Geothermal Energy Technology, Massachusetts Institute of Technology Energy Laboratory Report, MIT-EL 90-001.